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NUTRITIVE VALUE and CONSUMER ACCEPTANCE of FROZEN POULTRY

● INEZ PRUDENT

OHIO AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

FOREWORD

This study was planned to supplement previous work which had been done at the several colleges and stations on the retention of nutritive value, flavor and consumer acceptability of frozen poultry. This is a problem of importance in this state because of the high economic value of this type of farming in Ohio.

Roasters uniform in age, care and genetic background were processed and frozen in the laboratories of The Ohio State University Poultry Department. Wrapping consisted of a laminate of heavy butcher paper and aluminum foil. The lot was divided into thirds, and one part was stored at +10° F., one at 0° F. and the other at —10° F.

The technical assistance of Dr. Marian Wharton and Miss Virginia Norton of the Department of Home Economics and Miss Beth Alsup and Miss Ruth Martin, graduate students, is gratefully acknowledged. Appreciation is also accorded Dr. A. R. Winter of the Poultry Department, the Statistics Laboratory, The Ohio State University, and the five staff members who served on the panel.

CONTENTS

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SUMMARY

The effect of frozen storage at +10° F., 0° F., and —10° F. for a period of 18 months on the breast and thigh of broilers was studied by means of organoleptic and physical tests. Evidences of dehydration increased throughout the storage period but were much more serious at the highest temperature. At +10° F. a marked accumulation of ice crystals appeared in the interior of the birds along with the formation of a thickened white membrane lining the body cavity. This was less evident in those stored at 0° F. and —10° F.

Texture of the breast lost its elastic consistency early in storage and became granular and powdery, a change not considered objectionable by the panel of judges. Thigh muscles changed to some extent but did not become powdery. The flavor remained acceptable throughout the period of the experiment, although had the skin not been removed it is certain that the birds stored at +10° F. would have been found to be unacceptable long before the termination of the study.

Odor during cooking was unpleasant due to changes in the fat and proteins of the skin. It is noteworthy that birds stored at +10° F. for more than a year and badly freezer-burned, looked much more attractive after cooking but the skin was tough and comparable in texture to plastic tubing.

Temperature of storage did not seem to affect the juiciness of the breast tissue, but the dark meat lost juiciness as the duration of storage was lengthened. The percentages of press fluid extracted from both breast and thigh continued to increase until after a year of storage.

There was a slight decrease in volatile loss during roasting along with an increase in press fluid values and some decrease in percentage of dry weight of the samples.

Freezing increased the scores for tenderness of both light and dark muscles but storage did not greatly increase this effect.

Neither length of storage period nor temperature of storage affected the thiamine content of the cooked roasters or the amount lost in cooking.

Longitudinal histological sections of tissue can be used to study changes in structure during the storage period.

PROCEDURE

For this study it was possible to obtain from the Poultry Department of the College of Agriculture, The Ohio State University, a group of young cockerels which were hatched and reared in the course of a genetics experiment. They were the result of cross-breeding dominant White Plymouth Rocks and New Hampshires. They were raised under standard conditions to 23 weeks of age at which time most of them had attained a clean-dressed weight of 3½ to 4 pounds, although the range was 2¾ to 5 pounds.

They were killed, semiscalded in water at 128° F., dressed, and chilled in running water for two to three hours. They were individually wrapped in laminated aluminum foil, using a druggist's lock seal. The ends were folded over several times and secured with Scotch tape. The wrapping was pressed as close to the surface of the birds as possible to minimize the amount of air space inside the package.

The roasters were frozen at —20° F., and, with the exception of three birds, placed in equal numbers in three different storage compartments. One group was kept from then on at —10° F., one at 0° F., and one at +10° F. These temperatures were chosen because most locker plant operators and most manufacturers of home freezers recommend that frozen foods be kept in storage at 0° F., and many laboratories were inclined to state that —10° F. was preferable. It has been generally recognized that +10° F. was the upper limit at which frozen food storage should be considered.

A 20-degree spread was thought to be sufficient to make differences in quality-retention evident, if there were any of practical magnitude. It was borne in mind, also, that the cost of storage at +10° F. is considerably less than storage at 0° F. or —10° F., and that if quality can be maintained almost as well or as long at the highest temperature, it might be the most practical temperature for general use.

It was the plan to get just as much information as possible from data collected on the birds, and to continue the tests as long as the supply lasted. In order to minimize the error inherent in the multiple processes involved, three birds were removed from the lot before freezing, and at intervals of two months thereafter three were taken from each storage compartment for testing, making nine individual birds tested at each period. Limitations of the scoring panel used made it impractical to evaluate a large number of samples at one session, and

because of limited laboratory facilities, these tests were made, using a roaster from each different storage unit, every other day for three testing days.

The three birds to be used for the test on a particular day were removed at random one from each of the three groups in storage. These were examined and sawed in two along the breast bone with an electric band saw. The half on which the breast bone was retained was used for the tests on cooked meat, and the other half was used for tests to be run on the uncooked portion. The frozen halves were kept loosely wrapped in the refrigerator at 45° to 50° F. over night and the defrosting completed at room temperature the next morning.

The half of the bird containing the larger part of the breast bone was chosen for cooking because the breast muscles were protected from drying out more effectively during the roasting process. Because the breast meat of chickens is so different from leg muscle in texture, flavor, color, and tenderness it was decided to use for testing, samples taken from both breast and thigh, except in the case of thiamine determinations. In this case, it is well known that the dark muscles of the leg and thigh are richer in thiamine content than the breast meat, hence only the lower leg muscles were used.

TESTING PROCEDURE

The half to be cooked was weighed and the pH of the tissue was taken by inserting a glass electrode through the skin into the muscle tissue and reading the pH on a Beckman model G pH meter. A glass electrode having a cone-shaped tip especially made for such a purpose was used. Readings were taken in the pectoralis minor muscle which connects the breast and the wing and in the semitendinosus, which is the outside thigh muscle.

The half chicken was then placed skin side up on a triangular rack on a tray with a meat thermometer inserted into the thigh muscles, entering at the posterior dorsal border and lying almost parallel to the backbone. The birds were roasted simultaneously in a Dispatch rotary floor oven at 350° F. to an internal temperature of 190° F.

After roasting, the birds were cooled just enough for handling, weighed, the pH again taken at the same sites, and then the skin was removed. The large breast muscle, pectoralis major, the lower leg, and the thigh were removed. The lower leg was retained for thiamine determination, and the bone was cut from the muscles of the thigh. See Figure I.

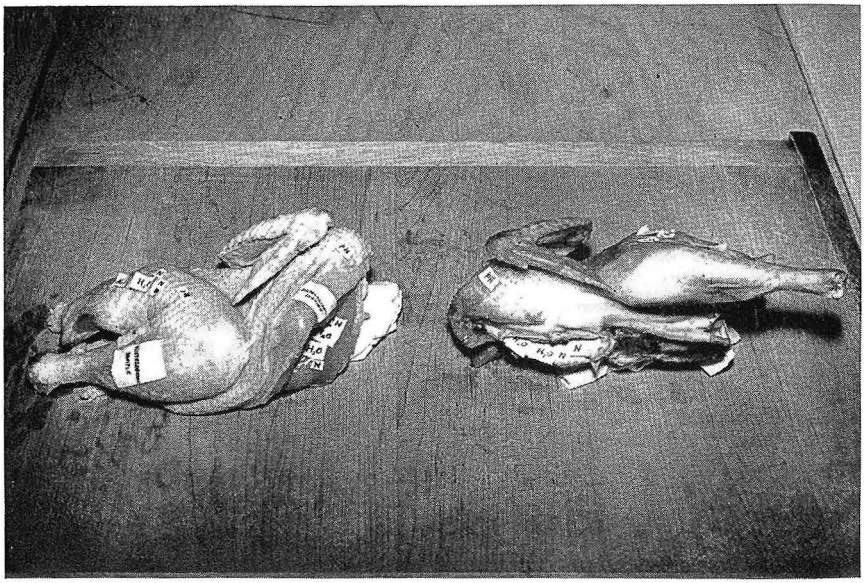

Fig. 1—Tags on these chickens indicate where samples for determination of pH, moisture content, nitrogen and histological analysis were taken. Procedure is described on page 5.

Although the original plans included fatty acid, fat aldehyde, and peroxide determinations, the amount of fat on most of the birds was not adequate for this part of the study.

ORGANOLEPTIC TEST

A panel of five research workers who would be available for judging throughout the entire period of the experiment and who were interested in the critical evaluation of food quality was arranged for. No preliminary training period was given, nor was it possible to select judges who had themselves proven to be most capable of discriminating small differences in flavor or texture of chicken tissue from a larger group.

Three men and two women of long experience in research, one recognized for excellence in dairy judging, one active in research in quality control of horticultural products, one a food and nutrition research associate, one in poultry research, and the other a research associate in equipment comprised the panel. They judged three to four samples of dark meat and the same number of white meat samples at a sitting, and recorded their scores.

The samples were prepared as follows: The pectoralis major was cut in two crosswise in approximately equal parts, and the anterior half was cut crosswise into strips beginning with the center of the muscle. After removing one strip for press-fluid determination these were assigned to the judges in alphabetical order. The thigh muscle tissue was removed intact from the bone and six samples cut crosswise. The third slice above the knee joint was used for press fluid determination; otherwise, the samples were used for the judges, assigned as above in alphabetical order. This caution was necessary in order that a judge might compare the tenderness of one sample with another from exactly the same anatomical position. To assist the judges, on several occasions a fresh bird comparable in age and type to those under test was roasted and cut into samples in a fashion identical with the procedure used for the frozen birds. This was identified as a control for the judges and was not scored.

The score card was the same as that used in poultry research by the Poultry Department and the Department of Home Economics at Iowa State College for studies on poultry. In this case, it was decided not to evaluate aroma, since it was impossible to assemble the judges at any specific time. This factor was also largely responsible for the decision to score the meat at room temperature. A scale from 0 to 10 was adopted for scoring, and the three qualities tenderness, juiciness and flavor were evaluated. Each sample was put upon a separate saucer and kept covered with a custard cup until judged. The judges were given water only along with the samples and were encouraged to score the samples before lunch or between 2 and 5 P. M.

PRESS FLUID DETERMINATIONS

Duplicate samples between 1.0 and 1.5 grams in weight were taken from the sections reserved for press fluid determinations. The breast sample was cut from a slice just posterior to the five samples cut for the judges and the thigh sample was cut from the third crosswise slice above the joint between the lower leg and the thigh. Each sample was weighed on a Torsion balance accurate to the third decimal place, pressed in a Carver laboratory press for 30 seconds under 500 pounds pressure per square inch. The moisture was absorbed by felt pads above and below the sample. The percentage of weight lost in the pressing is used as an index of the amount of press fluid.

MOISTURE DETERMINATIONS

The moisture determinations were made on duplicate samples of both cooked and uncooked halves of the birds using samples averaging one gram in weight, one set taken from the anterior three-fourths inch

of the pectoralis secundus and the other from the lower part of the biceps femoris. The samples were dried in an electric oven at 100° C. to constant weight and the percent of moisture loss calculated.

NITROGEN CONTENT

The total nitrogen was determined on triplicate samples from the breasts and thighs of each roaster by the usual Microkjeldahl procedure, using 300 to 400 mg. samples taken from the upper three-fourths inch of the pectoralis secundus and the lower part of the biceps femoris. After digestion the samples were diluted to 25 ml., and 3 ml. aliquots were used for distillation.

Formol titrations according to a modification by R. R. Sealock were attempted in the early stages. It was planned to follow the protein breakdown by means of formol titration which measure the free amino groups and ammonia group. The ammonia could be measured by the regular Parnas distillation and thus the increase in amino groups followed. The method proved not to be adapted to the conditions under which it was used. This is a phase of the investigation well worth recommending for further study.

THIAMINE CONTENT

The thiamine content of a slice cut from the thickest part of the lower leg including part of the gastrocnemius and several other muscles was determined on both the cooked and the uncooked tissue. The method used was the fluorometric procedure described in the 1947 edition of "Vitamin Assays" (1) by the Association of Vitamin Chemists. Duplicate five gram samples were used and the enzyme preparation used was takadiastase.

HISTOLOGICAL SECTIONS

On the day of defrosting and roasting, samples of breast and leg muscles were put in sample bottles containing the usual preservative, 10% formalin in normal saline solution. It was the plan to use these pieces of tissue for study of the breakdown of muscle fibers during the periods of storage at the three temperatures, +10° F., 0° F., and —10° F.

Embedding

The embedding method adopted was as follows: Thin longitudinal sections were cut and kept covered with 70 percent alcohol for two hours, then with 85 percent alcohol for one hour, fresh 85 percent alcohol for one hour, 95 percent alcohol for one hour, and finally in absolute alcohol for 1.5 hours. During this last period the alcohol was

changed at the end of 20 and at the end of 70 minutes immersion. If it was necessary to interrupt preparation of the section, the tissue was left in the 85 percent alcohol and subsequent dehydration carried out when work could be resumed.

The absolute alcohol was poured off and replaced with a 50:50 mixture of xylene and absolute alcohol, mixed just before using. After one hour, the liquid was changed to plain xylene and the tissue was allowed to stand from one to two hours. The second half of the time the tissue was placed in an oven at 60° C. The xylene was replaced with melted paraffin for two hours in an oven at 58° C. to 60° C. Any higher temperature tended to burn the tissues. A fresh paraffin treatment was then used for two hours at the same temperature. The tissue was quickly transferred to paper boats filled with fresh paraffin. Care was taken so that a film of paraffin did not solidify around the tissue. A warm needle was used to arrange the tissue in place. After a film had formed over the paraffin, the boat was plunged into cold water until the block was firm. At this stage sections could be stored.

Sectioning

After cutting away as much paraffin as possible without disturbing the tissue and keeping opposite sides parallel, the embedded tissue was sealed to the cutting block with melted paraffin. The block was placed in a rotary microtome so that the surface to be cut was parallel to the knife and adjusted to cut sections 10 to 20 microns thick. Albumin fixative in distilled water was used, sections were floated on slides, then slides were placed on a warming table. After sections had smoothed out, excess water was drained off. Sections were dried on the warming table overnight.

Staining

Slides were placed in staining beds and covered with xylene from which they were taken through a standard hematoxylin-eosin staining procedure.

The slide was then dried with cheesecloth, carefully avoiding the tissue which was not allowed to dry. It was then mounted in Clearite and placed on the warming table until the Clearite was dry.

Longitudinal sections of thigh and breast muscles were made of tissue from as many of the roasters as was possible. The characteristics of the muscle fibers were studied in an effort to tell whether powdery disintegration and cross-striation breakdown occurred to a greater extent or earlier in the birds stored at one temperature than at another. It was also planned to see when fiber breakdown occurred in frozen storage and what was the course of its progress.

RESULTS AND DISCUSSION

The results of the organoleptic tests on the 84 roasters are presented, followed by the mechanical and chemical findings. Raw data and statistical analysis are available from the author. Tables of mean values are presented in the Appendix.

APPEARANCE

Although the roasters had been closely wrapped in a laminate of heavy paper and aluminum foil, using a "drug store" lap and doubly folded ends, fastened in place with Scotch tape, some birds showed signs of desiccation early in the storage period. Roaster No. 5 which was stored only 56 days at +10° F. gave evidence of slight freezer burn. This was always more evident while the birds were frozen than after thawing. From this time on one or more of the birds taken from the freezer at +10° F. and 0° F. had the characteristic opaque light yellow patches around feather follicles due to moisture loss. The extent of the skin affected increased as the length of storage increased, from a few areas just above the tail to a dense coverage over the entire back, the legs and thighs, wings, and breast.

The first evidence of desiccation of the cavity was recorded in a bird stored six months at +10° F., which gave the appearance of a thin grayish-white collagenous sheath over one side of the cavity. Longer periods of storage increased the thickness of this white membranous layer on one side of the cavity of the birds stored at this temperature. Coarse rectilinear masses of ice crystals were pyramided in the other half of the cavity, the volume being dependent upon the temperature and the length of storage.

The contrast in the amount of desiccation at the end of one year of storage may be seen in Figure II. During the later months the white membrane covered the whole cavity wall, although it was much thicker on the side not covered with ice crystals. The membrane in all probability consisted of dehydrated, coagulated tissue proteins and was similar to the opaque areas surrounding the feather follicles on the skin, except for difference in fat content.

The earliest record of freezer burn on those birds stored at —10° F. was after eight months of storage, and consisted of a few small areas only. From this time on gradually increasing amounts were evident until at the end of the experiment it was estimated that 15 to 20 percent of the exterior was irregularly spotted with dehydrated areas.

Not until the roasters had been stored for 18 months at +10° F. was any decided off-odor noticed during the roasting period and while

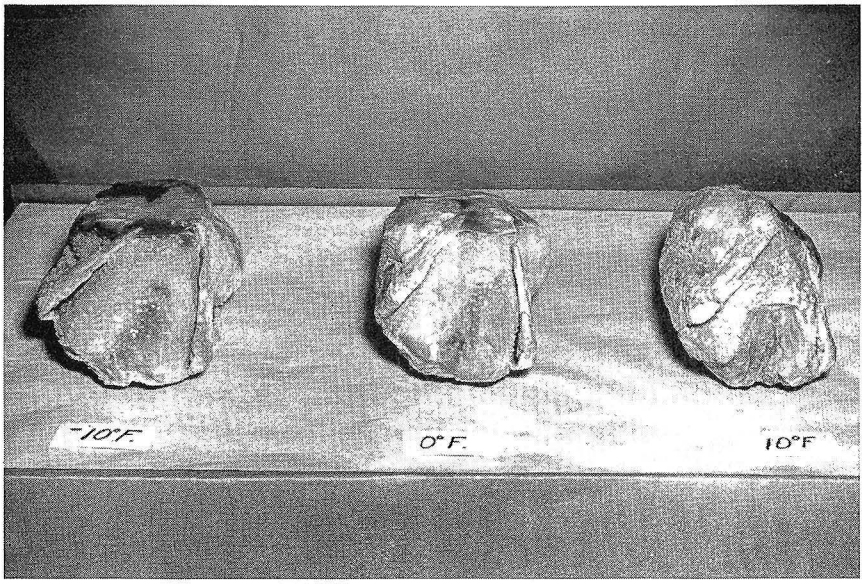

Fig. II.—Appearance of cockerels after 12 months' storage at the temperatures indicated. Note decreasing amounts of dehydration with lower storage temperature.

the birds were hot. It resembled the odor of rancid fat and was so potent that there was some question as to whether or not it was edible and would not be so persistent on the judges' palates as to influence the validity of the scores for the other samples. However, after the skin had been removed, the samples cut as usual, and cooled to room temperature, the judges, with one exception, failed to note any unusual or unpleasant odors.

ORGANOLEPTIC TESTS

The panel of five judges who scored the roasters during the entire experiment were not given previous training in scoring chicken tissue but they were chosen for their experience and interest in food research and their availability for judging throughout the entire period of the experiment. All were active in research at the time. Their appreciation of the careful and conscientious observation needed and their interest in the experiment partially compensated for the pre-training which in this case was not possible. Fresh roasters as nearly comparable as possible to those used in the experiment were purchased from local poultrymen, cooked and sampled for comparative purposes at

intervals during the course of the experiment. A great difference in texture between the muscles of the fresh and frozen birds was noticed, but the judges regarded the texture of the stored roasters so highly that the change in texture was not evident in their scoring. In some cases they preferred the more granular or fibrous texture of the frozen tissue to the elastic somewhat gummy texture of the freshly killed birds.

The judges each used his own set of criteria based on experience and attempted to keep in mind the characteristics of the tissues first scored to be used as the basis for scoring. Although samples from a freshly killed and cooked bird were made available for comparison, no attempt was made to agree on a score for this tissue, on the basis of which the test samples would then be scored. It was suggested that the system used by Lowe, namely counting the number of chews required to form a homogeneous bolus to be swallowed, be used in arriving at the score for tenderness. The samples from fresh chicken were the only standards available other than previous samples judged, so that the task of the judges was unusually difficult.

As a consequence of this set-up and of the minute differences between the samples, the judges differed greatly in their scoring of the birds. Statistical analysis showed that the variation due to scoring of individual judges was highly significant in all cases. Training or a scored standard sample available at each test period might have welded this group into a team of judges whose scores would be less variable and whose judgments would be more in accord. Such a trained panel would reflect changes in a product more adequately, but might not be a very good index of consumer acceptability. A standard scored reliably and available for use at intervals over an eighteen-month period would be of great value in improving the reliability of these evaluations.

Flavor

In the cases of both the breast and thigh, the fresh unfrozen roasters were given the highest scores for flavor (average of three birds). However, throughout the storage period of eighteen months the average scores for the breast fall between the limits of 7.13 and 8.20 (possible scores one to ten). Each score in Table 1 represents the arithmetic mean of three chickens which were stored at the same temperature the same length of time. During the period the scores fluctuated up and down for roasters stored at each of the test temperatures (—10° F., 0° F., and +10° F.) but the general trend was slightly downward, as shown in Figure III. It is remarkable that, even when stored at +10° F. for so long a time, the flavor should have been retained to such an extent that the average scores never fell below 7 for the breast nor

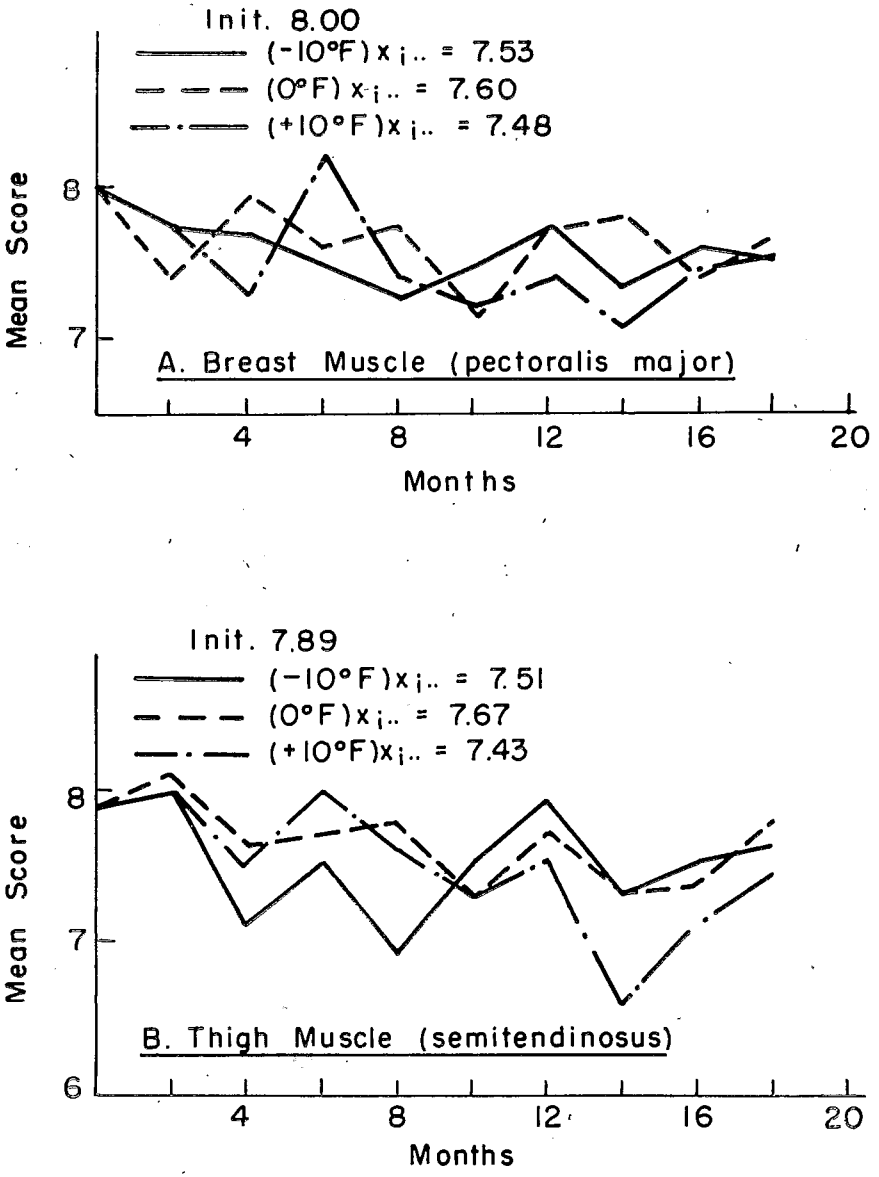

Fig. III.—Judges' scores for flavor of roasters stored at three temperatures for varying periods of time.

TABLE 1.—Means of Judges' Scores for Flavor of Roasters Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	8.00	7.89				
2 Months	7.73	8.00	7.40	8.13	7.73	8.00
4 Months	7.67	7.13	7.93	7.67	7.27	7.53
6 Months	7.47	7.53	7.60	7.73	8.20	8.00
8 Months	7.27	6.93	7.73	7.80	7.40	7.60
10 Months	7.47	7.53	7.13	7.33	7.20	7.00
12 Months	7.73	7.93	7.73	7.73	7.40	7.53
14 Months	7.33	7.33	7.80	7.33	7.07	6.60
16 Months	7.60	7.53	7.40	7.47	7.47	7.13
18 Months	7.53	7.67	7.67	7.80	7.50	7.47
Mean of group stored at indicated temperature	7.53	7.51	7.60	7.67	7.48	7.43
Grand Mean	7.54 – breast 7.54 – thigh					

below 6.6 for the thigh. In one instance, a chicken stored at +10° F. for 14 months, the average of scores given by the judges was 5.8 for the breast (8, 8, 6, 3, 5) and 4.8 for the thigh (8, 4, 5, 3, 4). In another stored for 18 months at this same temperature, severe freezer burn was noted and a strong, persistent, highly objectionable off-flavor developed in the upper part of the thigh where the muscle layer between the bone and the desiccated skin was very thin. The remainder of the thigh, rated by the other judges, scored 8, 9, 7, and 8, while this upper section scored 2.

Considering the entire storage period, the trend was toward a gradual decrease in flavor as the storage period increased in length, regardless of the temperature of storage. According to an analysis of the variance between the flavor scores of the frozen roasters, that due to the judges was the only component falling within the five percent probability zone, and neither the variance due to temperature nor to length of storage was of significant magnitude.

Such retention of flavor in frozen storage was considered remarkable and was probably due in part to the excellent initial quality of the roasters, to the relatively small amount of fatty tissue exposed to oxidation, to the careful packaging, and to the quality of the wrapping material.

Juiciness

The scores for juiciness of the breast of those roasters frozen and stored at all three temperatures decreased upon freezing and fluctuated irregularly around the initial frozen bird value thereafter (Figure IV and Table 2).

This initial decrease accompanied a change in texture from a gummy, elastic somewhat tough consistency to a granular texture from which moisture was more easily expressed and in which the juiciness seemed to be augmented. It seems reasonable to assume that the initial freezing so concentrated the solids of the muscle cells that constituent proteins were coagulated. The ice crystals formed probably broke through confining membranes in some cases and water was more available for formation of ice crystal deposits in the empty spaces within the package or for evaporation losses during cooking.

It will be noted that the average scores for juiciness in the breast of the birds stored at +10° F. were consistently low beginning with the birds stored for eight months. Values for roasters stored at lower temperatures were, in general, higher during these last 10 months of the experiment. Perhaps in the first case water was not available for rehydration of tissue as it was thawed, while in the second and third cases, smaller crystals resulted in less extensive loss of tissue fluids. Thus, although coagulation was presumably the same in the case of all three storage temperatures, available moisture resulting in an impression of juiciness was greater in the breast muscles of those stored at 0° F. and —10° F.

In contrast to the marked change in the juiciness and texture brought about by freezing the breast muscles, the texture and juiciness of the thigh muscles were changed little if at all by freezing (Figure IV and Table 2). Probably the water-binding capacity of the collagen, which is present in so much greater amount throughout these dark muscles than in the light, as well as the structure of the particular muscle protected the tissue from moisture loss and thus retained its initial juiciness after cooking.

The juiciness of the thigh changed very little due to freezing. Statistical analysis showed that the variance in scores for juiciness of the

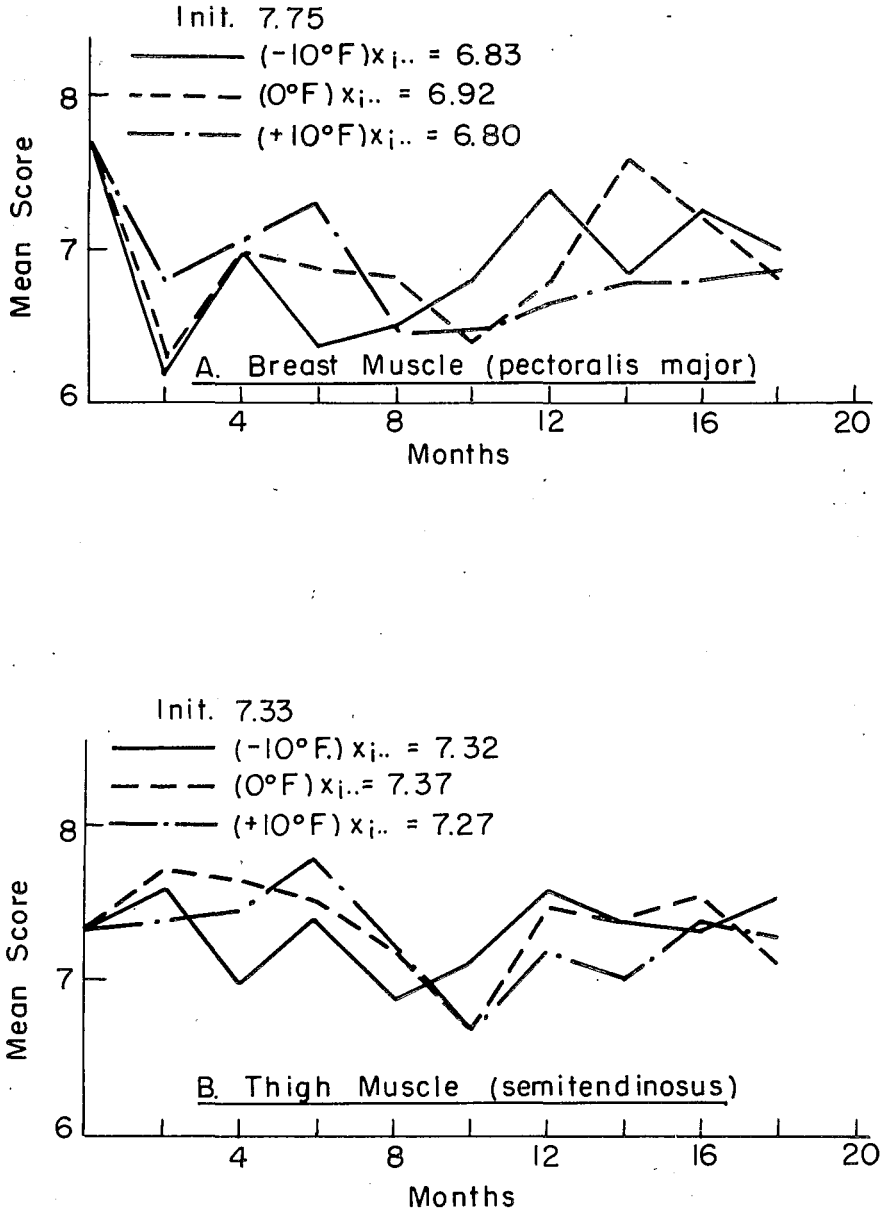

Fig. IV.—Judges' scores for juiciness of roasters stored at three temperatures for varying periods of time.

TABLE 2.—Means of Judges' Scores for Juiciness of Roasters Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	7.75	7.33				
2 Months	6.20	7.60	6.27	7.73	6.80	7.40
4 Months	7.00	7.00	7.53	7.67	7.07	7.47
6 Months	6.40	7.40	6.87	7.53	7.27	7.80
8 Months	6.53	6.87	6.80	7.20	6.47	7.20
10 Months	6.80	7.13	6.40	6.67	6.47	6.67
12 Months	7.40	7.60	6.80	7.47	6.67	7.20
14 Months	6.87	7.40	7.60	7.40	6.80	7.00
16 Months	7.27	7.33	7.20	7.53	6.80	7.40
18 Months	7.00	7.53	6.80	7.13	6.87	7.27
Mean of group stored at indicated temperature	6.83	7.32	6.92	7.37	6.80	7.27
Grand Mean	6.85 — Breast 7.32 — Thigh					

frozen breast due to judges was highly significant but not that due to temperature or length of storage. For the thigh, however, the variance (decrease in juiciness) during storage due to length of storage was highly significant as was variance due to judge. The component of the variance due to temperature of storage was not significant.

It may be noted here that the change in texture from a gummy elastic one to a granular one with liquid easily expressed as the teeth bit into the cooked tissue, was not objectionable to the judges. In fact, it was more acceptable than the freshly cooked tissue in several instances.

Tenderness

The means of judges scores are shown in Figure V and Table 3. The scores for tenderness of the breast increased irregularly during the storage period, and were after 18 months almost a score above the initial unfrozen chicken scores for this characteristic. This is in agreement with common observation. Probably the freezing itself was responsible for most of the tenderizing effect. Statistical analysis showed that variation due to the judges, to the length of storage and to the interaction of storage and temperature were all highly significant.

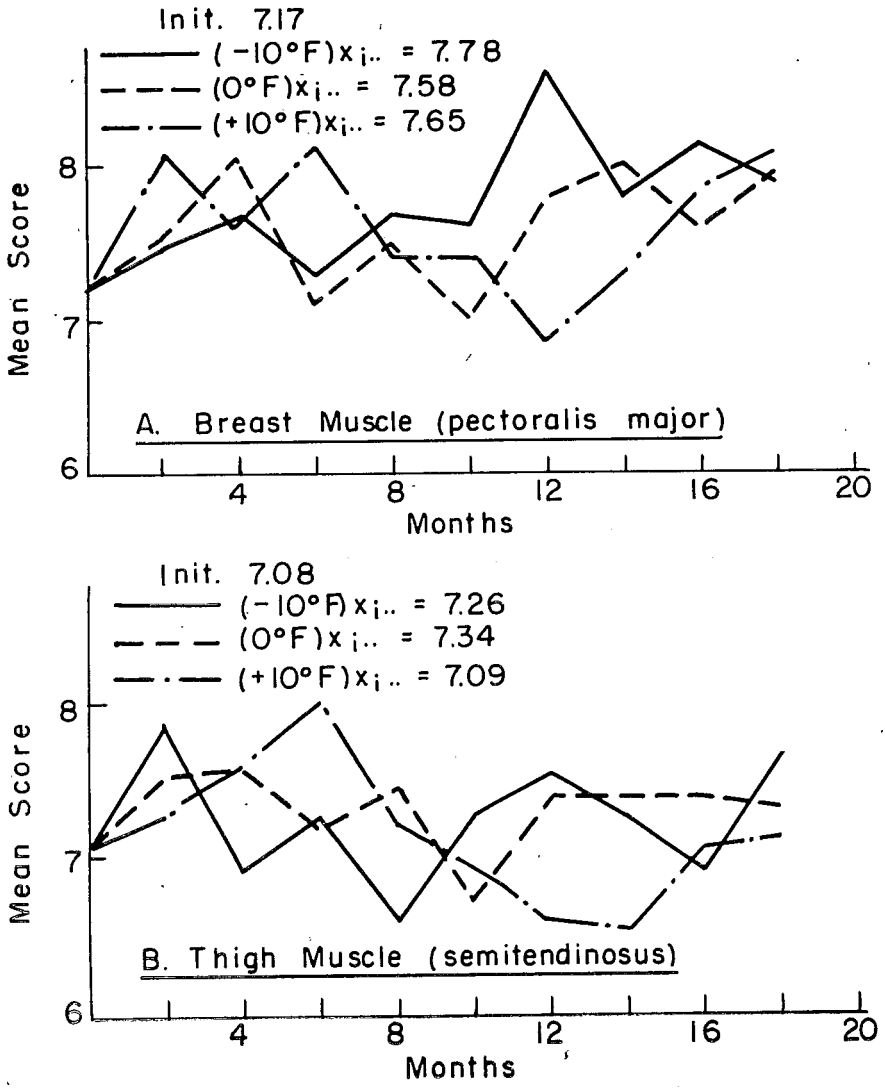

Fig. V.—Judges' scores for tenderness of roasters stored at three temperatures for varying periods of time.

TABLE 3.—Means of Judges' Scores for Tenderness of Roasters Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at −10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	7.17	7.08				
2 Months	7.47	7.87	7.27	7.53	8.07	7.27
4 Months	7.67	6.93	8.07	7.60	7.60	7.07
6 Months	7.27	7.27	7.07	7.20	8.13	8.00
8 Months	7.67	6.60	7.47	7.47	7.40	7.20
10 Months	7.60	7.27	7.00	6.73	7.40	6.93
12 Months	8.60	7.53	7.80	7.40	6.80	6.60
14 Months	7.80	7.27	8.00	7.40	7.27	6.53
16 Months	8.13	6.93	7.60	7.40	7.80	7.07
18 Months	7.87	7.67	7.93	7.33	8.07	7.13
Mean of group stored at indicated temperature	7.78	7.26	7.58	7.34	7.65	7.09
Grand Mean	7.67 — Breast 7.23 — Thigh					

The scores for tenderness of the thigh increased markedly after freezing and were variable according to storage temperature after that time. The variation due to the difference in scoring by the judges was highly significant and that due to the interaction of length of storage period and temperature was significant, but only at the five percent level of probability. Freezing seems to have increased the tenderness of both breast and thigh muscles.

Storage increased the tenderness of the frozen breast although it decreased the juiciness. It was noted that the breast tissue was powdery in texture, but a large amount of fluid was pressed out in carving or between the teeth. This was probably interpreted by the judges as juiciness although the appearance and flavor of the fluid expressed were much different from that expressed from freshly cooked chicken. This was true in less measure in the case of thigh muscles. It probably was associated with progressive denaturation of the cell proteins and redistribution of the moisture content of the tissue. It would be of interest to know whether this change in texture and water distribution was accompanied by a change in the ratio of bound to free water in the tissue.

PRESS FLUID DETERMINATIONS

Uncooked

The press fluid determinations were made by the method previously described on 1- to 2-gram samples of tissue after it had reached room temperature. The breast tissue sample consisted of a cross section abut 0.3 inch wide from one muscle, the pectoralis major, so that duplicate samples usually agreed closely. The thigh tissue used was a strip almost across the middle of the thigh. It consisted of several strips of muscle tissue loosely held together by connective tissue in which more or less fat was enmeshed. Samples taken from this tissue varied within wide limits in the amount of fluid extracted at a standard pressure applied for a standard length of time.

The percentages of press fluid extracted from the breast tissue increased markedly during storage up to 16 months, regardless of storage temperature (Figure VI and Table 4). The effect of storage, according to analysis of variance, was highly significant. This expressible fluid was probably responsible for the increasing scores for juiciness of breast given by the panel of judges.

TABLE 4.—Percentages of Press Fluid Expressed from Roasters Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	34.48	25.81				
2 Months	35.62	24.72	37.35	26.48	34.62	25.48
4 Months	36.08	31.09	39.13	28.53	38.49	31.43
6 Months	37.17	31.63	34.43	30.45	35.94	26.51
8 Months	37.17	29.60	38.85	30.45	37.44	30.37
10 Months	39.87	29.93	41.69	31.93	38.33	32.58
12 Months	*38.93	34.92	39.24	33.44	39.12	33.49
14 Months	38.09	31.33	43.84	34.47	42.11	28.54
16 Months	41.01	29.22	42.81	31.03	42.03	33.19
18 Months	35.50	23.11	39.50	25.65	39.17	24.02
Mean percentage for indicated storage temperature	37.72	29.51	39.65	30.27	38.58	29.51
Grand Mean	38.65 — Breast 29.76 — Thigh					

*Mean of two values instead of three.

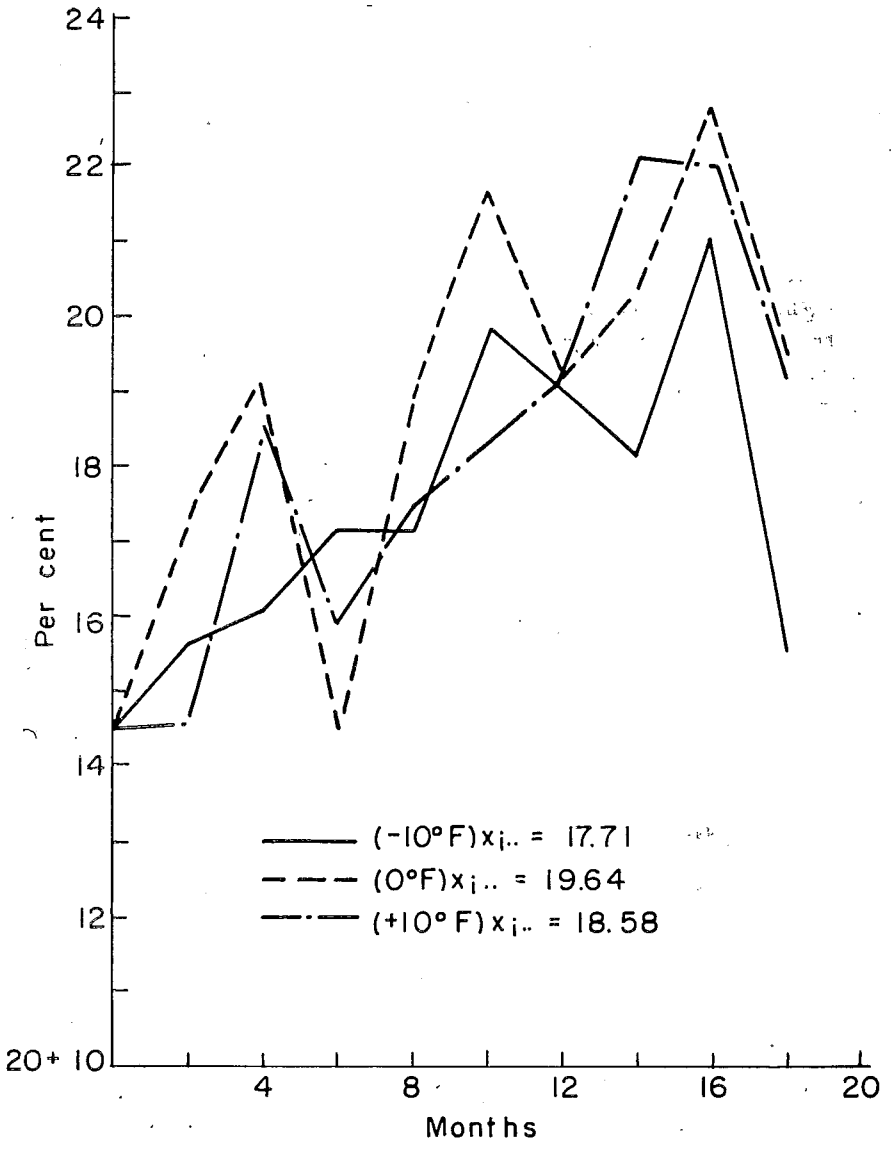

Fig. VI.—Percentage of press fluid extracted from breast muscle (pectoralis major) of roasters stored at three temperatures for varying periods of time.

The values for press fluid extracted from the thigh increased up to the twelfth month when roasters were stored at —10° F. and +10° F. and the fourteenth month when stored at 0° F. (Figure VII and Table 4). No explanation is offered for the subsequent slight decrease. It is possible that some of the water most easily displaced had evaporated and the vapor had been deposited as ice crystals elsewhere in the thigh or outside the carcass. Perhaps drip loss was greater in the birds stored a longer period of time. The effect of storage of thigh tissue on the press fluid extracted at these three temperatures for sixteen months was not significant. According to the scores of the judges after marked decrease in early storage periods, prolonged storage resulted in an increase in juiciness. It is probable press fluid values and scores of panel judges for juiciness were measures of the same characteristic.

DRY WEIGHT DETERMINATIONS

Uncooked Tissue

Samples of uncooked breast and thigh were dried at 100° F. to constant weight by the usual procedure and the percentage of dried tissue in relation to original weight was calculated. Very little change in this relationship was noted up to one year (Figures VIII, IX and Table 5). Those roasters stored at —10° F. and 0° F. decreased slightly

TABLE 5.—Percentage Dry Weight in Uncooked Breast and Thigh of Roaster Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	24.45	23.85				
2 Months	24.80	22.87	24.73	23.23	25.33	23.47
4 Months	25.70	23.27	25.67	22.93	25.53	23.47
6 Months	25.23	22.97	24.90	22.87	25.20	23.83
8 Months	25.00	23.37	24.90	23.33	25.33	23.57
10 Months	25.07	23.43	25.10	23.10	25.27	23.60
12 Months	25.57	22.67	25.03	22.90	24.90	23.30
14 Months	24.57	22.60	24.50	23.40	25.40	23.50
16 Months	24.73	22.53	24.40	22.37	24.80	22.93
18 Months	26.23	24.13	25.97	23.00	26.07	23.70
Mean percentage for indicated storage temperature	25.21	23.09	25.02	23.01	25.31	23.49
Grand Mean	25.18 — Breast 23.20 — Thigh					

in percentage dry weight after being in storage for fourteen months. Those stored at all temperatures were considerably below the mean percent of dry weight after storage for 16 months. At the final storage period, the percentage of dry weight had increased slightly in the case of all three groups. Analysis of variance showed that differences due to length of storage, but not temperature of storage were highly significant.

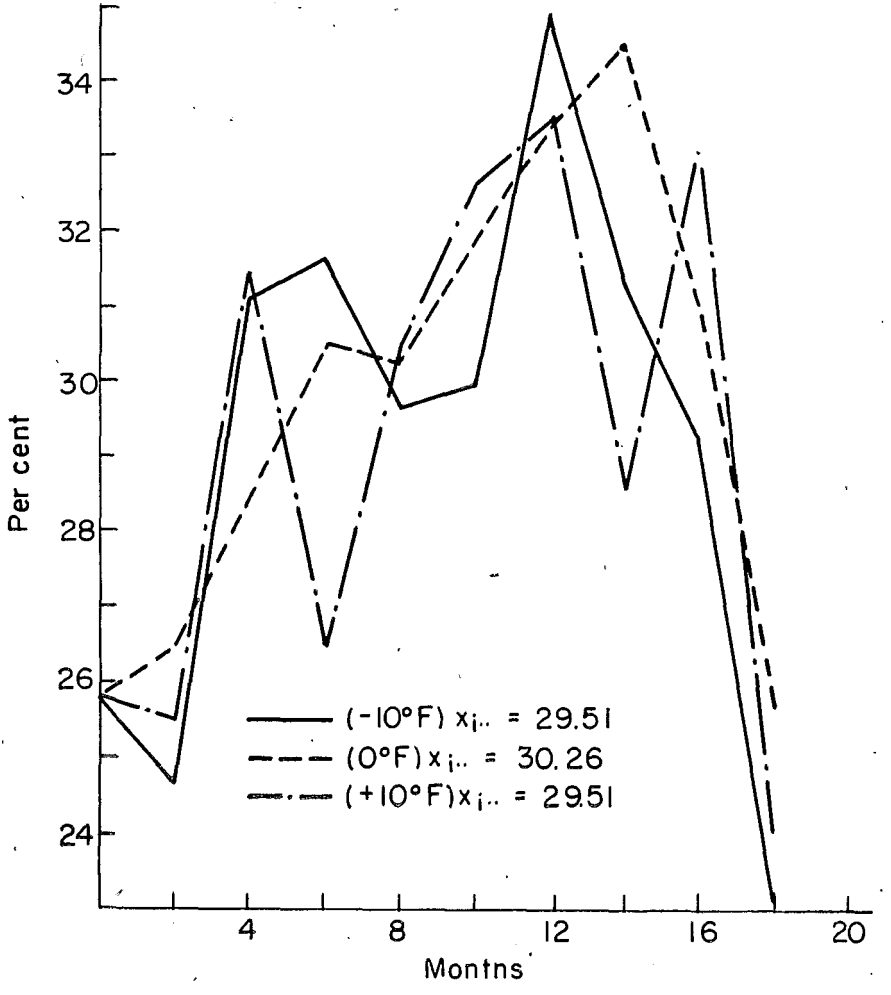

Fig. VII.—Percentage of press fluid extracted from thigh (semitendinosus) of roasters stored at three temperatures for varying periods of time.

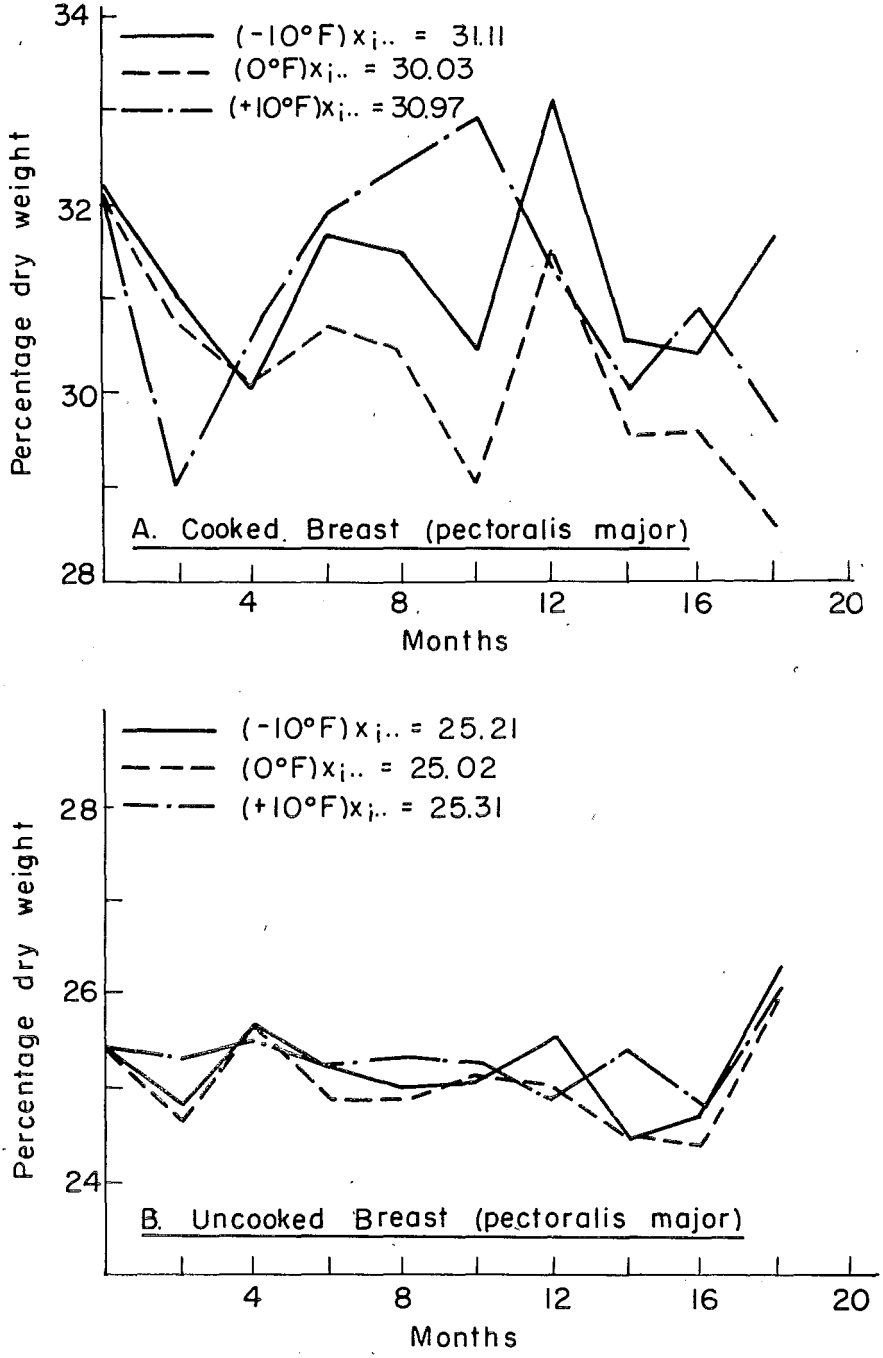

Fig. VIII.—Percentage of dry weight compared with total weight of breast of roasters stored at three temperatures for varying periods of time.

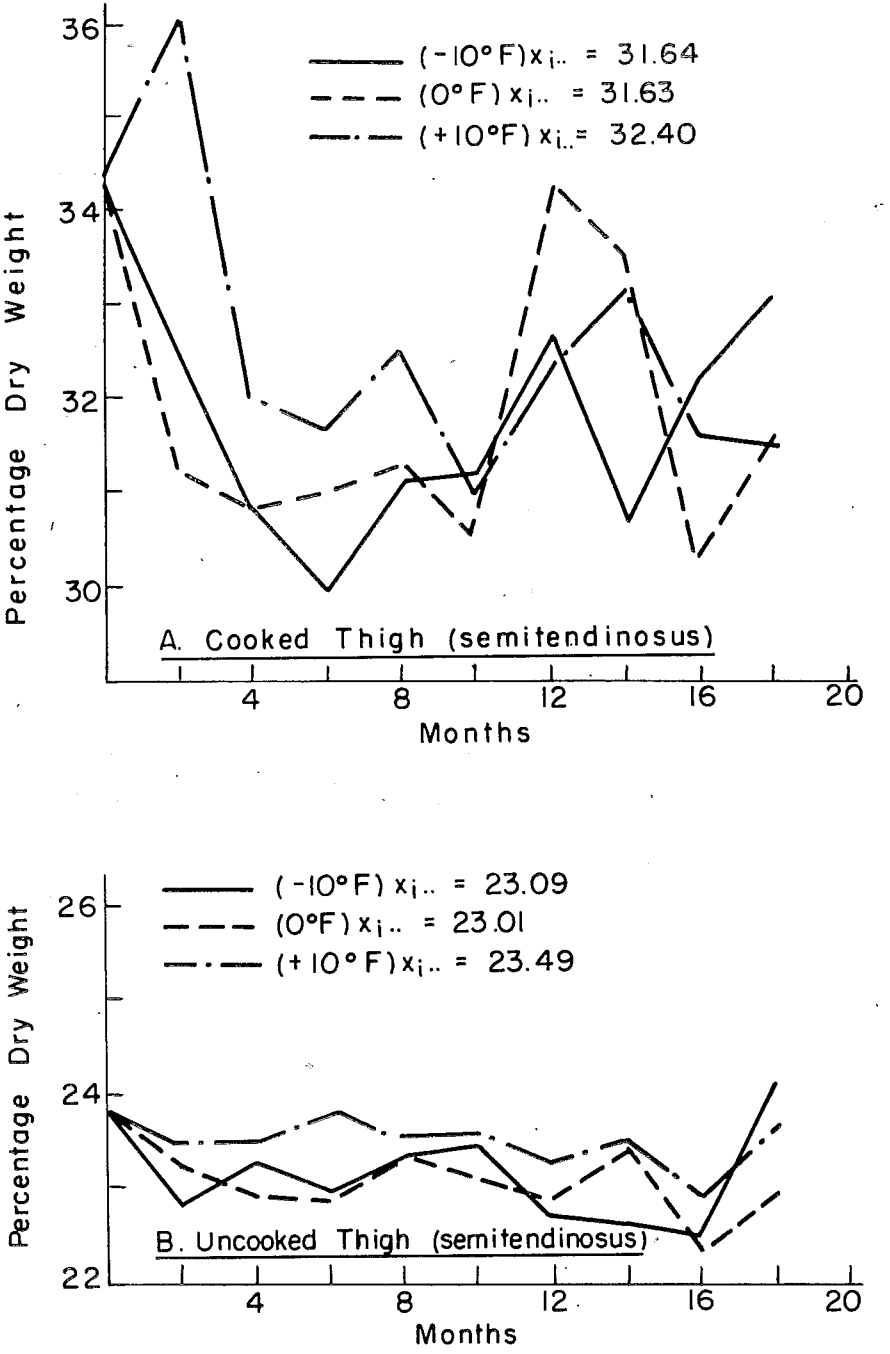

Fig. IX.—Percentage of dry weight compared to total weight of thigh tissue of roasters stored at three temperatures for varying periods of time.

The uncooked thigh consistently gave results lower in moisture content than the breast by about two percent. The means of the percentages for dry weight of tissue stored at +10° F. were higher than those for birds stored at lower temperatures, except at the final test period. The general trend for percentage of dry weight was slightly downward, except for an increase of 0.6 to 1.7 percent at the last period similar to the increase in dry weight of the breast tissue. According to analysis of variance the effect of temperature on percentage of dry weight was significant at the five percent level.

Cooked Tissue

The ratio of dry weight to moisture in cooked tissue is dependent not only on the ratio originally present but also on the processing and the sampling (Figures VIII, IX and Table 6). It was possible to cut the breast sample from a single muscle low in fat and connective tissue, but the thigh samples were less uniform in fat and connective tissue content. The amount and integrity of the skin covering the area from which the sample was excised and how well it was protected by its position during roasting were also important factors. When the removal of samples for judging was made it was inevitable that some juice was lost. Every effort was made to choose an area for samples least susceptible to these possible errors, and also to protect the samples from desiccation previous to and during the weighing. As would be expected the range of values for the cooked tissue and the inconsistency from one test period to another were much greater for the cooked than for the raw tissue. Except in two instances the cooked breast tissue had a lower percentage of dry weight than the initial samples of unfrozen roasters, and in those cases the increase was less than one percent. The fluctuations were erratic and the statistical analysis did not indicate any significant effect of temperature or length of storage period.

The same is true of the thigh tissue. Except for one of the duplicate samples of tissue in one roaster which was very high in dry weight (46.31 percent) the values for percentage of dry weight are lower than those of similar samples taken from the unfrozen birds. This indicates that the moisture content of tissues after cooking is actually higher in frozen than in fresh chicken after cooking. This is true to a slight extent in breast tissue but to a much larger extent in thigh tissue. However, for dry weight the trend of values of cooked thigh during the whole storage period and at all storage temperatures used was highly erratic and the statistical analysis showed the variability to be due to factors other than length or temperature of storage.

TABLE 6.—Percentage Dry Weight in Cooked Breast and Thigh of Roaster Stored at Three Temperatures for Varying Periods of Time

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	32.19	34.25				
2 Months	31.00	32.50	30.77	31.27	29.03	36.03
4 Months	30.03	30.83	30.10	30.83	30.53	31.97
6 Months	31.67	29.97	30.70	31.03	31.90	31.63
8 Months	31.47	31.10	30.47	31.30	32.40	32.50
10 Months	30.43	31.77	29.03	30.57	33.07	31.00
12 Months	33.10	32.67	31.47	34.27	31.30	32.27
14 Months	30.50	30.70	29.57	33.50	30.00	33.13
16 Months	30.40	32.20	29.60	30.33	30.87	31.60
18 Months	31.43	33.07	28.57	31.57	29.67	31.50
Mean percentage for indicated storage temperature	31.11	31.64	30.03	31.63	30.97	32.40
Grand Mean	30.71 — Breast 31.89 — Thigh					

Both relative moisture content and press fluid of the cooked tissue increased markedly in the early weeks of frozen storage. This increase was not shown to a great extent by analysis of the uncooked muscle, but was strikingly evident after cooking. Texture change, indicated by the panel scoring, as well as this increase in easily removable moisture content, would point to drastic alteration of the protein-moisture relationship. Heat-processing seems to affect the water-binding power of the cell proteins to a much greater extent than in unfrozen tissue. It may be a matter of partial denaturation with release of loosely bound water, or with simple mechanical break-down of confining membranes.

VOLATILE LOSS IN WEIGHT

The volatile loss in weight of the roasters is of interest in relation to the apparent juiciness, the press fluid, and the moisture content of the tissue. See Table 7. Loss in weight is reported as percent of uncooked weight. This is somewhat in error because of unavoidable variations in sawing frozen birds and native differences in the proportion of bone and muscle tissue and surface exposed. However, the average losses of the

TABLE 7.—Volatile Loss During Roasting, Expressed as Percentage of Uncooked Weight

Storage Period	Stored at +10° F.		Stored at 0° F.		Stored at —10° F.		Average
2 Months	# 5	27.5	# 4	22.2	# 6	29.0	
	# 7	20.8	# 9	22.9	# 8	20.8	
	#10	15.9	#12	19.5	#11	19.1	22.0
4 Months	#13	19.2	#14	17.7	#15	19.9	
	#16		#18		#17		
	#21		#20		#19		
6 Months	#22	23.5	#23	13.9	#24	25.9	
	#25	21.1	#27	21.1	#26	22.7	
	#29	24.9	#28	25.0	#30	23.2	22.4
8 Months	#32	20.5	#31	19.7	#33	22.3	
	#36	10.6	#34	21.1	#35	17.2	
	#39	25.1	#37	22.6	#38	22.1	20.1
10 Months	#41	19.8	#40	19.4	#42	16.4	
	#45	24.1	#43	28.5	#44	20.8	
	#47	18.9	#48	20.4	#46	20.7	21.0
12 Months	#49	18.6	#50	19.6	#51	23.4	
	#53	21.4	#52	16.4	#54	23.9	
	#55	21.3	#56	19.9	#57	20.1	20.5
14 Months	#59	15.6	#58	19.9	#60	18.8	
	#62	19.8	#61	19.4	#63	20.4	
	#65	19.7	#64	16.5	#66	21.9	19.1
16 Months	#67	17.8	#69		#68	20.9	
	#70	23.1	#72	21.5	#71	23.8	
	#73	19.7	#75	16.4	#74	20.3	20.3
18 Months	#76	18.9	#77	17.9	#78	21.9	
	#81	18.3	#79	19.0	#80	20.6	
	#84	18.3	#82	15.8	#83	20.2	18.9

three birds removed at each storage temperature as well as the combined average of the nine studied at each period indicate a slight progressive decrease in the volatile loss (about 2 percent during a 16-month period).

This decrease in volatile loss was accompanied by an increase in press fluid values and a slight decrease in percentage of dry weight in the samples.

NITROGEN CONTENT

According to the original plan of this experiment an attempt was to have been made to follow the course of protein breakdown during frozen storage by the formol titration which measures the free amino groups. Correction was to have been made for terminal amino groups of the basic amino acids by subtracting the ammonia nitrogen as determined by the Parnas distillation method. Since both these values would need to be calculated as a ratio of the total nitrogen, Kjeldahl determinations were made on samples of breast and thigh tissue. It was not possible to complete this phase of the project as planned, but the values for total nitrogen (exclusive of ring-N) are presented, determined by the usual Microkjeldahl procedure calculated as percent of moist uncooked sample.

It is to be expected that changes in the total nitrogen content of a section of tissue during a long period of storage might be brought about by dehydration in which case the percentage of nitrogen would be increased, or by reorientation of water in which the nitrogen might be increased or decreased according to whether moisture in the sample area was increased or decreased. Enzyme action would not be expected to make changes in the nitrogen content drastic enough to be determined by this method. Otherwise, changes during storage must have been due to differences in the roasters themselves, variation in the fat-protein relation or the different proportions of the various proteins such as myosin, collagen, and elastin in the section excised and analyzed. In calculating the amount of nitrogen per 100 grams of uncooked tissue, due recognition was accorded the fact that the uncooked tissues were not identical in moisture content. The range of variation of the averages of the three groups in moisture content was only 0.1 percent, a value too small to make calculation of each value on a dry weight basis worth while.

During storage the nitrogen content of the uncooked breast of all three groups of birds was decreased slightly, calculated on the basis of milligrams of nitrogen per 100 grams of uncooked muscle (Figure X and Table 8). These differences between the means were significant only at the five percent level. This change was associated with a change in dry weight of this muscle which was highly significant, so that increase in relative water content must have compensated for the decrease in relative protein content as length of the storage period increased. However, since nitrogen determinations were made on the same samples as dry weight determinations this matter will bear further investigation.

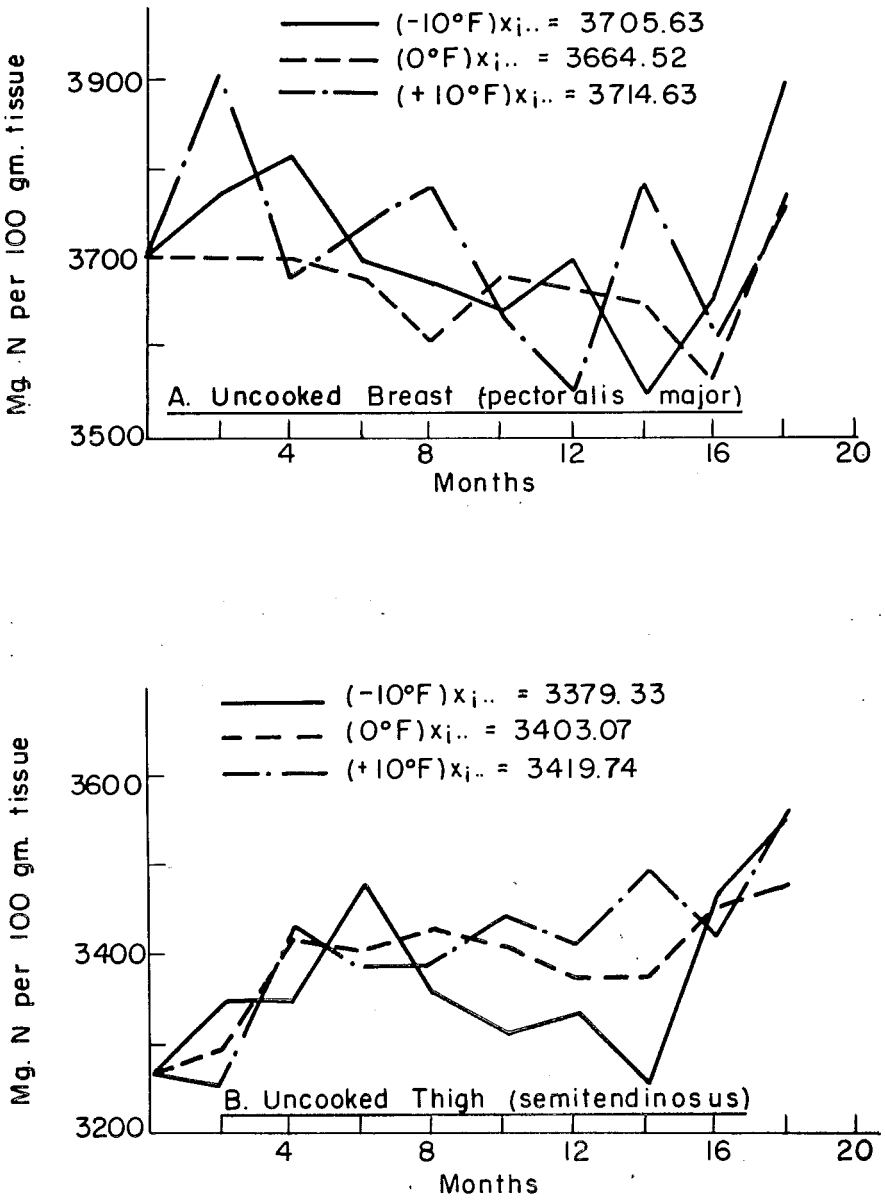

Fig. X.—Total nitrogen content of roasters stored at three temperatures for varying periods of time (percent of sample).

TABLE 8.—Total Nitrogen Content of Uncooked Roasters Stored at Three Temperatures for Varying Periods of Time (mg per 100 gm of sample)

Length of Storage	Stored at —10°F. Breast – Thigh		Stored at 0°F. Breast – Thigh		Stored at +10 F. Breast – Thigh	
0	3707.00	3270.70				
2 Months	3774.67	3343.66	3692.67	3296.33	3904.33	3257.67
4 Months	3812.67	3343.33	3702.00	3416.00	3677.00	3432.00
6 Months	3695.67	3460.00	3674.67	3401.67	3728.33	3380.00
8 Months	3667.00	3357.00	3601.67	3424.00	3778.67	3390.67
10 Months	3639.00	3308.33	3675.67	3407.33	3631.00	3441.00
12 Months	3697.33	3331.67	3663.33	3376.33	3546.00	3408.00
14 Months	3520.67	3259.67	3645.67	3372.33	3782.33	3494.67
16 Months	3652.00	3461.33	3559.00	3455.00	3626.00	3414.33
18 Months	3891.67	3549.00	3766.00	3478.67	3758.00	3559.33
Mean percentage for indicated storage temperature	3705.63	3379.33	3664.52	3403.07	3714.63	3419.74
Grand Mean	3694.93 – Breast 3400.72 – Thigh					

The dry weight and nitrogen values for the samples of cooked breast were not consistent in their variations and no relation to length or temperature of storage can be noted (Figure XI and Table 9). This is true of cooked thigh samples as well.

The nitrogen values of the thigh muscle used rose slightly with length of storage in the case of those birds kept at +10° F. and at 0° F., but those kept at —10° F. showed such a decrease that calculation showed that temperature was a significant factor. At the latter part of the storage period values for this group (—10° F.) attained as high a level as that of the other two groups. It might be that this low temperature has a deterring effect on protein and moisture changes in the tissue.

Dry-weight percentages and total nitrogen percentages of both cooked and uncooked tissue in more than half of the mean values show a sharp rise between 16 and 18 months of storage at all temperatures of storage. There is no known variation in handling, or storage or elsewhere in the experimental procedure to account for this, and, for the present, it remains unexplained.

HYDROGEN ION CONCENTRATION

The pH of the uncooked tissue varied irregularly around pH 6, with a trend toward somewhat greater acidity as length of storage increased. Just what this means in biochemical terms is somewhat vague, but evidently amino groups were increasingly tied up, and acidic groups were increasingly freed, either terminal or by partial hydrolysis of the peptide linkages.

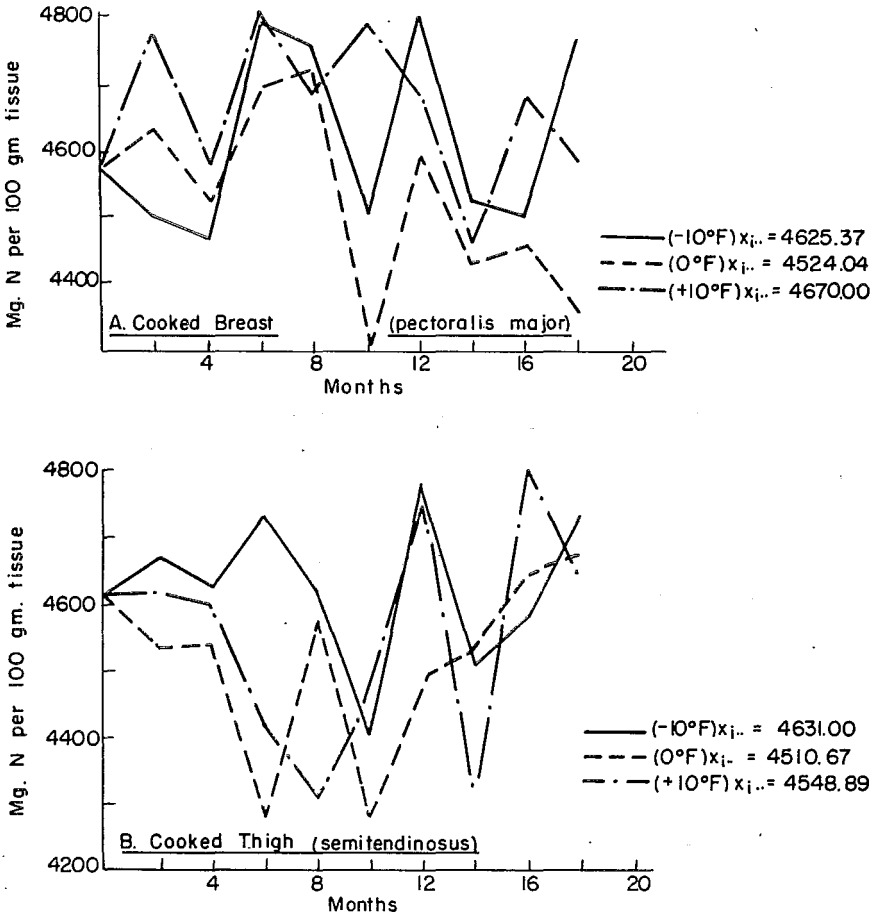

Fig. XI.—Total nitrogen content of roasters stored at three temperatures for varying periods of time (percent of sample).

TABLE 9.—Total Nitrogen Content of Cooked Roasters Stored at Three Temperatures for Varying Periods of Time (mg per 100 gm of sample)

Length of Storage	Stored at —10°F.		Stored at 0°F.		Stored at +10°F.	
	Breast	Thigh	Breast	Thigh	Breast	Thigh
0	4573.33	4621.00				
2 Months	4502.00	4677.00	4634.67	4543.67	4782.33	4621.67
4 Months	4470.67	4630.33	4523.00	4546.67	4582.67	4600.00
6 Months	4796.33	4741.67	4692.67	4285.00	4805.67	4422.67
8 Months	4760.67	4626.33	4723.67	4586.00	4682.67	4315.67
10 Months	4505.33	4406.67	4303.00	4277.33	4787.00	4472.00
12 Months	4801.00	4777.33	4598.67	4495.00	4675.00	4755.00
14 Months	4521.33	4510.67	4430.00	4539.00	4453.00	4323.33
16 Months	4500.33	4578.67	4457.67	4647.33	4679.67	4793.00
18 Months	4770.67	4730.33	4353.00	4676.00	4582.00	4636.67
Mean percentage for indicated storage temperature	4625.37	4631.00	4524.04	4510.67	4670.00	4548.89
Grand Mean	4606.47 — Breast 4563.52 — Thigh					

The pH of the cooked tissue varied irregularly on either side of pH 6.5 from 5.91 to 7.20. As length of storage increased the pH increased slightly. Temperature of storage had little or no effect on the hydrogen ion concentration of the muscles examined.

Analysis of variance indicates that length of storage is responsible for a highly significant increase in acidity in the uncooked roasters. In the cooked roasters there was a marked increase in alkalinity. Water and volatile constituents are the only constituents lost during the cooking process and nothing was added. Proteins and fragments of protein molecules must form cross linkages or otherwise tie up carboxyl groups during cooking to a greater extent than amino groups are liberated. It is not likely that changes in inorganic constituents are involved.

THIAMINE CONTENT

Uncooked Tissue

The thiamine level in fresh uncooked tissue (average of three birds) was 5.588 micrograms per gram of dry tissue. This is somewhat lower than that reported by Erdsiek and her associates (2) in 1951 (7.7 micrograms per gram of dry fat-free tissue) and Millares and Fellers (3) in 1949 (8.8 micrograms, calculated on the same basis as the value

given by Erdsiek). These roasters assayed somewhat higher in thiamine than those of Morgan et al. (4) in 1949 which adjusted to the dry fat-free basis would be 2.5 to 4.0 micrograms per gram.

The values in this study were not corrected for fat content of tissue since the visible fat was exceedingly low in all the birds. Erdsiek found a fat content of 5.39 percent in her experimental tissues which was obtained from chickens similar in age and treatment to the roasters used in this study. Adjustment of the values to consider such a fat content would increase the values reported, since these figures are on the dry, but not fat-free basis. The basis used in this report was considered satisfactory for answering the questions investigated in this study, namely, does length of storage or temperature of storage (+10° F. and —10° F.) affect thiamine retention in roasters.

It will be noted in Figure XII and Table 10 that neither length of storage nor temperature within the limits of this study affected the thiamine content of these samples of uncooked leg mucle. The values

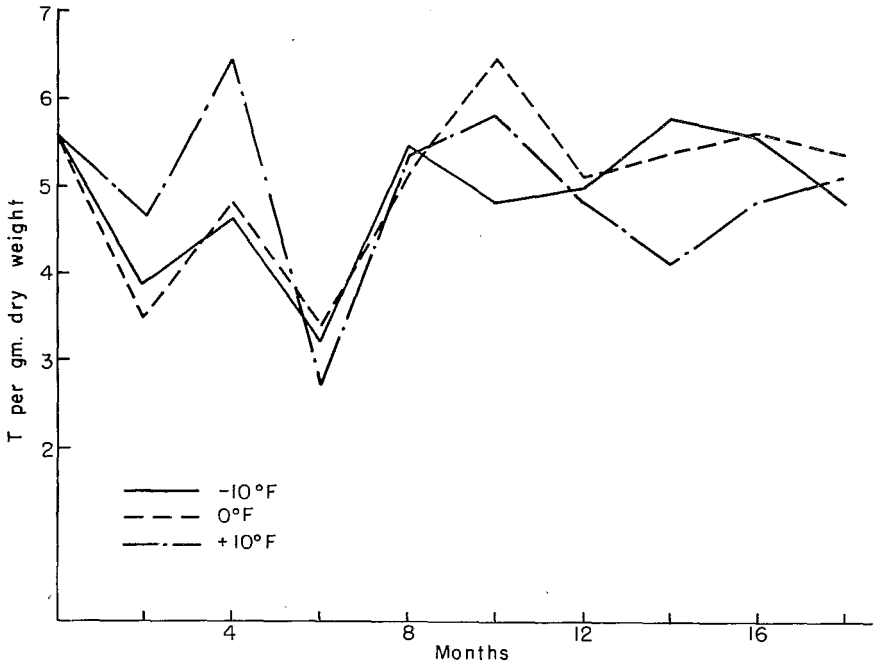

Fig. XII.—Thiamine content of uncooked leg muscles of roasters stored at three different temperatures for varying periods of time.

TABLE 10.—Thiamine Content of Uncooked Leg Muscles of Roasters (mcg/gm dry tissue) Stored Varying Periods of Time

Storage Period	Stored at +10° F.		Stored at 0° F.		Stored at —10° F.	
0 Months	#1	5.362				
	2	6.687				
	3	4.714				
2 Months	5	5.157	#4	2.330	#6	2.880
	7	3.885	9	4.806	8	4.915
	10	5.040	12	3.478	11	3.777
4 Months	13	9.520	14	5.034	15	4.946
	16	6.757	18	3.936	17	5.723
	21	3.231	20	5.525	19	3.047
6 Months	22	3.460	23	4.188	24	4.589
	25	1.432	27	1,158	26	1.179
	29	3.237	28	4.900	30	3.832
8 Months	32	5.619	31	4.798	33	4.797
	36	5.210	34	5.680	35	6.193
	39	5.379	37	5.070	38	5.425
10 Months	41	4.764	40	6.990	42	4.639
	45	5.662	43	5.431	44	4.618
	47	7.061	48	6.820	46	4.684
12 Months	49	4.449	50	3.629	51	3.932
	53	4.357	52	4.208	54	4.912
	55	5.573	56	6.869	57	6.044
14 Months	59	3.571	58	5.258	60	4.817
	62	4.287	61	5.377	63	6.102
	65	4.608	64	5.366	66	6.382
16 Months	67	5.666	69	5.922	68	5.359
	70	4.317	72	4.851	71	5.068
	73	4.494	75	6.030	74	6.087
18 Months	76	4.433	77	5.751	78	6.313
	81	5.619	79	5.440	80	3.315
	84	5.334	82	4.941	83	4.678
Mean		4.893		4.955		4.750
Mean of stored roasters		4.866				

from bird to bird varied greatly as might be expected of such an active metabolite. The range in values ran from 1.158 to 9.520 micrograms per gram of dry tissue, the maximum being seven times the minimum value. Sixty-two percent of the values were 4 or 5 micrograms in close approximation to the mean of 4.866. Only six percent were below three and 17 percent above six.

Cooked Tissue

The thiamine content of the samples of fresh birds birds roasted to an internal temperature of 190° F. was 3.268 micrograms per gram of dry tissue (Figure XIII and Table 11). Since before cooking these roasters had a thiamine content of 5.588, the loss due to cooking was 41.5 percent. Erdsiek (1951) reports a loss of 56 percent in cooking similar birds by a similar method.

It is well recognized that comparisons of values on uncooked and cooked tissue based on dry weight are not, in reality, comparable because of the difference in composition and properties of the tissues after cooking. In cooking, fat, water, electrolytes, and probably some nitrogenous material is exchanged or lost, and the protein is coagulated.

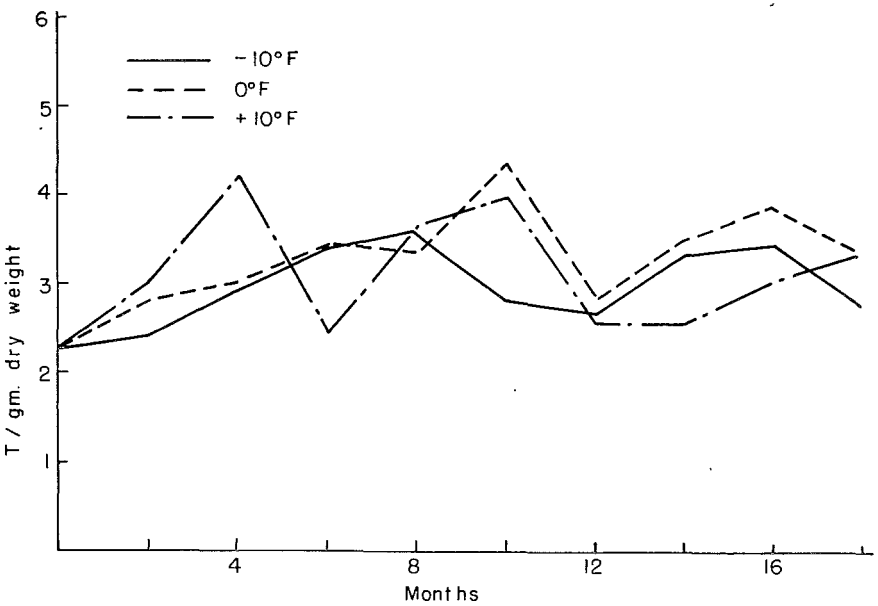

Fig. XIII.—Thiamine content of cooked leg muscles of roasters.

TABLE 11.—Thiamine Content of Cooked Leg Muscles of Roasters (mcg/gm dry tissue) Stored Varying Periods of Time

Storage Period	Stored at +10° F.		Stored at 0° F.		Stored at —10° F.	
0 Months	#1	3.488				
	2	2.285				
	3	4.034				
2 Months	5	2.774	#4	3.372	#6	1.557
	7	3.489	9	3.327	8	2.749
	10	2.803	12	2.676	11	2.902
4 Months	13	5.554	14	2.667	15	3.363
	16	4.490	18	2.981	17	3.903
	21	2.578	20	3.543	19	1.551
6 Months	22	3.786	23	3.385	24	3.647
	25	0.957	27	4.253	26	2.763
	29	2.623	28	2.757	30	3.812
8 Months	32	3.879	31	3.186	33	3.308
	36	3.858	34	3.662	35	4.066
	39	3.295	37	3.175	38	3.441
10 Months	41	2.948	40	4.661	42	2.968
	45	3.974	43	3.900	44	2.984
	47	4.869	48	4.523	46	2.429
12 Months	49	2.850	50	2.051	51	2.117
	53	2.531	52	2.507	54	2.643
	55	2.223	56	3.910	57	3.209
14 Months	59	2.333	58	3.504	60	3.162
	62	2.452	61	3.411	63	3.356
	65	2.802	64	3.598	66	3.391
16 Months	67	3.550	69	4.107	68	3.631
	70	2.703	72	3.775	71	3.214
	73	2.854	75	3.720	74	3.433
18 Months	76	2.837	77	3.305	78	3.434
	81	3.582	79	3.801	80	1.867
	84	3.660	82	2.888	83	2.928
Mean		3.195		3.394		3.032
Mean of stored roasters		3.207				

The texture is so changed that the proportion of bound and free water is altered in an unknown fashion. Since, however no acceptable formula for accurate comparison can be given, it is helpful to examine the relationship of the values which are available.

Observation of Figure XIII and Table 11 will show that neither length of storage period nor temperature of storage affected the thiamine content of the cooked roasters or the amount lost in cooking.

The mean thiamine value for all the cooked stored samples was 3.207 while that of the uncooked stored samples was 4.866 micrograms per gram. This constitutes a cooking loss of 34.3 percent, roughly seven percent below the loss in cooking the fresh samples. It is doubtful if this is to be considered a difference worthy of note, although it may indicate that duration of storage does not increase losses during processing.

In four cases, namely roasters 4, 22, 26, and 27, the thiamine content of the leg muscles after cooking was greater than the content of the uncooked muscles. In two of these, numbers 4 and 22, the difference is not great and could easily have been due to difficulties of sampling. In numbers 26 and 27, and also in number 25 the values for the uncooked tissues are all atypically low. These determinations were run at the same time and an error in the thiamine standard or in some step of the calculation seems probable.

The extent of thiamine loss during cooking was not as great for frozen as for fresh cockerels, the mean being 32.6 percent for frozen compared with 41.8 percent for fresh samples. Why this should be so, if indeed it is, is hard to explain and no light is thrown on the matter by any aspect of this study.

HISTOLOGICAL STUDIES

All histological work was done on uncooked tissue. Longitudinal sections were mounted and stained with hemotoxylin to observe the progress and extent of breakdown in the muscle. Samples were taken from each of the nine different storage periods but only a portion of the tissue proved suitable for study.

Technical problems encountered were: scarcity of persons trained in histological technique; resulting storage of samples beyond optimum time for histological study; difficulty in making sections parallel to the muscle fiber, especially in tissue from the thigh; and fragility of tissue from the breast muscle.

In studying the stained sections made from the roasters, these were the items noted: whether or not fibers were intact and, if not, what was the extent of mutilation; whether or not the cross striations were

clearly discernible in the fibers; whether the bands forming the cross striations were close together or widely separated; whether nodes, kinks and sharp curves were numerous or sparse; and whether or not there was any evidence of the granular disintegration of both fiber content and fiber wall to be seen in aged muscle.

Breast Muscle

The stained sections of those roasters processed without freezing showed some fractures across fibers but the fibers were otherwise intact and cross striations were visible and regular. Few kinks and nodes were visible, for rigor had been well dispelled by the time the roasters were processed.

In those roasters stored at —10° F., the fiber break-up which is probably responsible for the granular texture of frozen breast tissue was evident to a slight extent after two months of storage. It increased in intensity and was noted in a majority of the fibers after 10 months in most birds. Tissue from one bird stored 12 months at this temperature was an exception. Those tissues which had undergone storage for 16 to 18 months were badly fragmented. In the fragments, even at the end of the experiment, the cross striations were still visible in some fibers. They appeared, however, to be more widely separated in those samples of tissue which had been stored eight months or longer. Kinks, nodes, and sharp curves characteristic of tension on muscle were numerous until after 12 months of storage and were not evident in the sections from birds stored longer.

All breast tissue was fragile and very difficult to cut and mount. This became increasingly so as the duration of frozen storage lengthened.

In the sections made from those roasters which were stored at 0° F. fragmentation of tissue increased with increasing length of storage, beginning after six months of storage. Cross striations remained visible throughout the study. Nodes and similar formations were numerous until after 10 months of storage.

The sections from roasters stored at +10° F. were quite fragmentary and difficult of interpretation. Cross striations remained visible, but were widely separated during the last 10 months of storage. Nodes disappeared after two months of storage.

In summary, breast tissue is fragile and difficult to section after freezing and becomes increasingly so with increase in storage time or temperature. Fewer nodes, which are usually associated with toughness, appear as temperature of storage increases and they tend to dis-

appear as the time in storage is increased. In the fragments of muscle fiber, even after 18 months of storage, the cross striations may be seen spaced regularly but farther apart than in the case of fresh tissue.

No study as limited technically as this could pretend to do any more than state what seems apparent based on the material at hand. Further work on this phase would be profitable and worthwhile with increased technical skill as well as experience in interpreting results.

Thigh Muscles

In the leg, the semitendinosus was the muscle from which the section was preferably obtained. In those roasters which were not frozen the fibers were intact, cross striations were visible and there were some curves and kinks. Throughout the storage period at all three temperatures cross striations could be seen, but, as in the case of breast tissue, the bands appeared more widely separated during the last six months of storage. Nodes and irregularities of the fiber were more numerous than in the case of breast tissue and they persisted in some measure throughout the storage period at all temperatures. The tissue remained intact until after 12 months of storage when stored at —10° F.

In summary, leg muscle retains the integrity of its muscle fibers much longer than breast muscle, and also the accompanying irregularities of structure such as nodes, kinks, and the like. Perhaps this is a matter of collagen and elastic content rather than the muscle fiber itself. Cross striations are visible and regular all through the storage period used. The stability of this type of muscle is probably related to the retention of characteristic texture longer than in breast muscles. Decrease in fiber integrity appeared to take place earlier in roasters stored at +10° F. than in those stored at —10° F.

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